Tape Calendering Manufacturing Process For Multilayer Thin-Film Solid Oxide Fuel Cells

Monthly Status Report
June 2002

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TAPE CALENDERING MANUFACTURING PROCESS FOR MULTILAYER THIN-FILM SOLID OXIDE FUEL CELLS

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This report summarizes the work performed for June 2002 reporting period under Contract DE-AC26-00NT40705 for the U. S. Department of Energy, National Energy Technology Laboratory (DOE/NETL) entitled "Tape Calendering Manufacturing Process For Multilayer Thin-Film Solid Oxide Fuel Cells". The main objective of this project is to develop a manufacturing process based on tape calendering for multilayer solid oxide fuel cells (SOFC's) using the unitized cell design concept and to demonstrate cell performance under specified operating conditions.

The unitized cell concept places a multilayer ceramic cell in a metallic housing with its own gas manifolds to form a complete cell package. Thus, unitized cells can be operated as a single unit and can be easily stacked. The multilayer cell contains a thin electrolyte for reduced temperature (<800^{o}C) operation and each cell component may consist of multiple layers for performance enhancements. This work involves cost analysis of unitized cell production, development and definition of the tape calendering fabrication process, and characterization of fabricated cells, including electrochemical performance testing to demonstrate efficient operation under desired conditions.

Task 1 under Phase I was completed in February, 2001. Task 2 and 3 of Phase II were completed in January 2002. Tasks 4 and 5 have been planned and are currently active. Progress under various tasks is summarized below.

Task 2.0: Manufacturing Cost Study – The purpose of this task is to update the preliminary cost estimate under Phase I to account for progresses in material, design, and fabrication developments and to quantify the impact of these modifications on manufacturing cost. The plan is to evaluate the cost of various configuration options for the unitized cell. The various configurations have differences in gas entry and exit manifolds, cell dimensions, and fabrication steps. Additionally, performance or power density may vary. Refinements will be made as performance data become available and designs and process steps are improved.

There was no significant activity under this task during this reporting period.

Task 3.0: Cell Configuration and Manufacturing Feasibility

Subtask 3.1. Multilayer Cell Fabrication

This work is divided into four major efforts: (1) Reduce operation temperature, (2) Improve electrochemical performance, (3) Improve cell flatness, and (4) Improve mechanical properties. Cell performance analysis are performed to assess performance losses from each cell component, which in turn guide component engineering and development of manufacturing processes to increase cell performance and reduce operating temperature.

This task was complete.

Subtask 3.2. Unitized Cell Fabrication and Design

The work plan is to (1) Down-select a suitable unitized cell design, (2) Design flow fields, (3) Fabricate and test parts, and (4) Test unitized cell assemblies. Under Phase I, cell design was narrowed down to focus on seal elimination. Based on this approach, different cell geometry and flow field options were evaluated and a single design was selected.

This task was complete.

Task 4.0: Manufacturing Process Development

Subtask 4.1 Process Development and Optimization

The objective of this subtask is to establish a preliminary definition of the fabrication process from cell fabrication to the assembly of unitized cell. The processes for the engineered cathode and anode establised under Task 3.1 will be scaled up and optimized. Critical process parameters will be identified and the sensitivity of these parameters on performance and fabricability will be studied. The cell size target is 8 in. The unitized cell configuration and flow field selected under Task 3.2 will be fabricated and unitized cells with engineered electrodes will be tested. The target performance is 250 mW/cm^2 at 700 C with simulated reformed natural gas.

This month, the first 4.5-in by 4.5 in. cell using an anode flow field pattern previously defined by CFD (for uniform flow distribution) was tested. Results of this cell test at 800 C are summarized below.

- The cell, NO-233, achieved an excellent of OCV: 1.095 V with 750 cpm flow rate of $64H_2/36N_2$ fuel and 1.037 V with a 250 cpm flow rate over an active area of 100-cm^2.
- The cell sustained up to 85% fuel utilization, the highest obtained to date for a 100-cm^2 active area cell.
- Polarization curves at different flow rates are shown in Figure 1 while curves at different fuel utilizations are shown in Figure 2. The performance of 215 mW/cm^2 at 0.7V with 75% fuel utilization for this cell is comparable to that of a previous cell. The performance of this cell is, however, much better than the last cell at higher fuel utilizations. This cell achieved a power density of 200 W/cm^2 at 0.7 V and 80% fuel utilization whereas the other was not able to reach 0.7 V under the same fuel utilization. This performance at 80% fuel utilization has been the highest obtained to date for a 100-cm^2 active cell area.

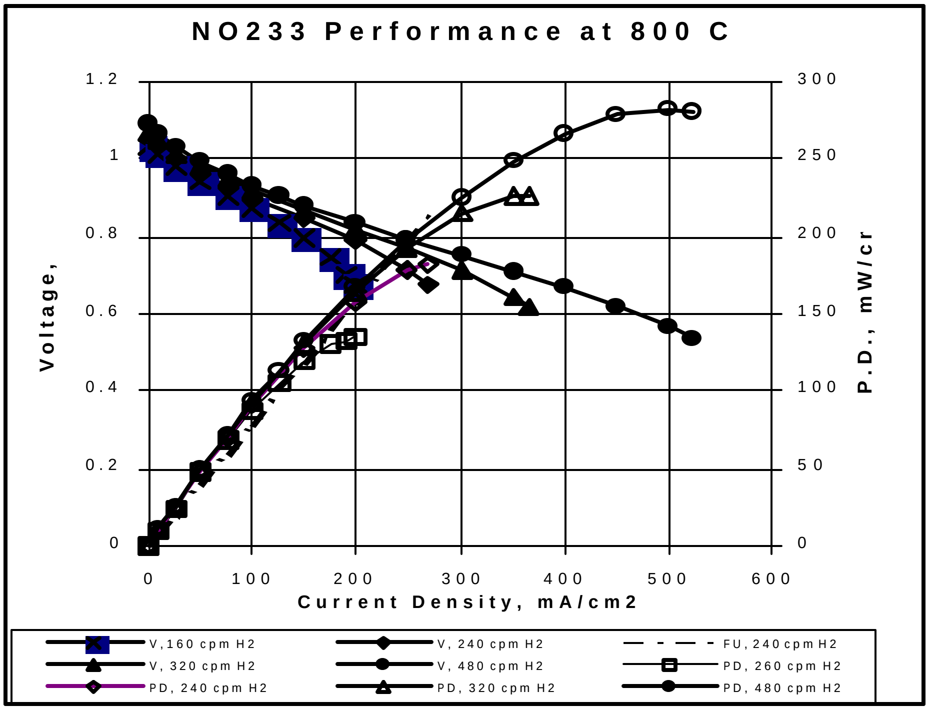

Figure 1. Cell NO-233 Performance at 800 C under Different Fuel Flow Rates

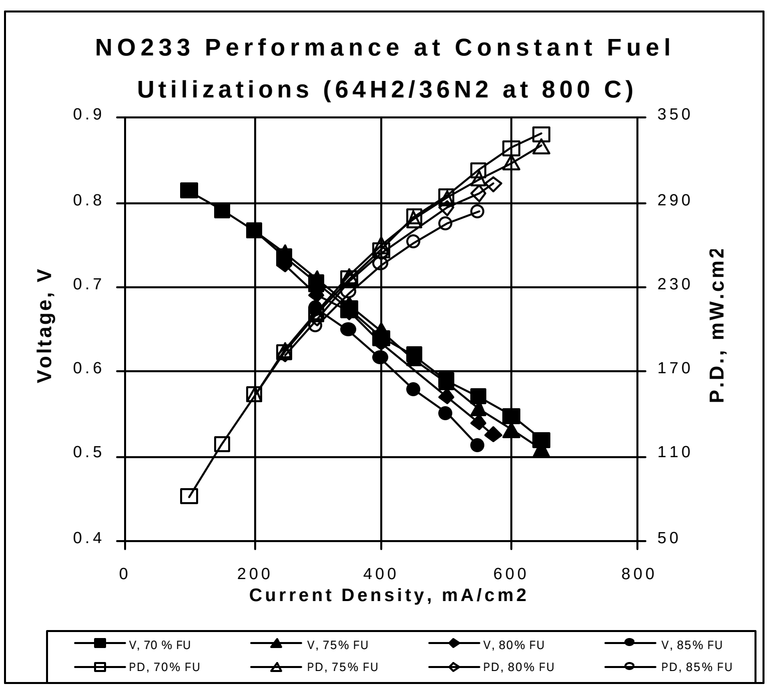

Figure 2. Cell NO-233 Performance at 800 C under Different Fuel Utilizations

Cell NO-233 was also tested at 750 and 700 C. Results at these temperatures are given below.

- The performance curves at 750 C under different flow rates are shown in Figure 3 while those under constant fuel utilizations are shown in Figure 4. The cell sustained over 0.7V with up to 60% fuel utilization. At 0.7 V and 60% fuel utilization, the power density was 120 mW/cm^2.
- The performance curves at 700 C under different flow rates are shown in Figure 5 while those under constant fuel utilizations are shown in Figure 6. The cell sustained over 0.7V with at least 50% fuel utilization. At 0.7 V and 50% fuel utilization, the power density was 70 mW/cm^2.
- Although these power densities below 800 C are low, this cell has been the first of 100 cm^2 size to demonstrate fuel utilizations of greater than 50% with voltages of over 0.7 V at these temperatures.

The cell was held at a constant load of 300 mA/cm^2 and 70% fuel utilization at 800 C for a period of 313 hrs. The voltage curve with time is shown in Figure 7. The voltage increased from 0.721 V to a maximum of 0.745 V over a period of 56 hrs. Thereafter, voltage gradually decreased at a nearly linear rate of about 15% per 1000 hrs. Although this decay rate is high, it is consistent with previously measured cell module data.

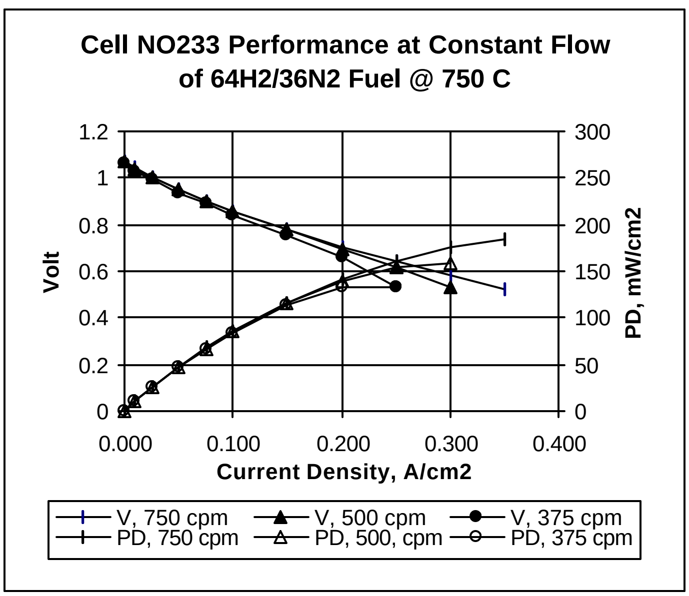

Figure 3. Cell NO-233 Performance at 750 C under Different Fuel Flow Rates

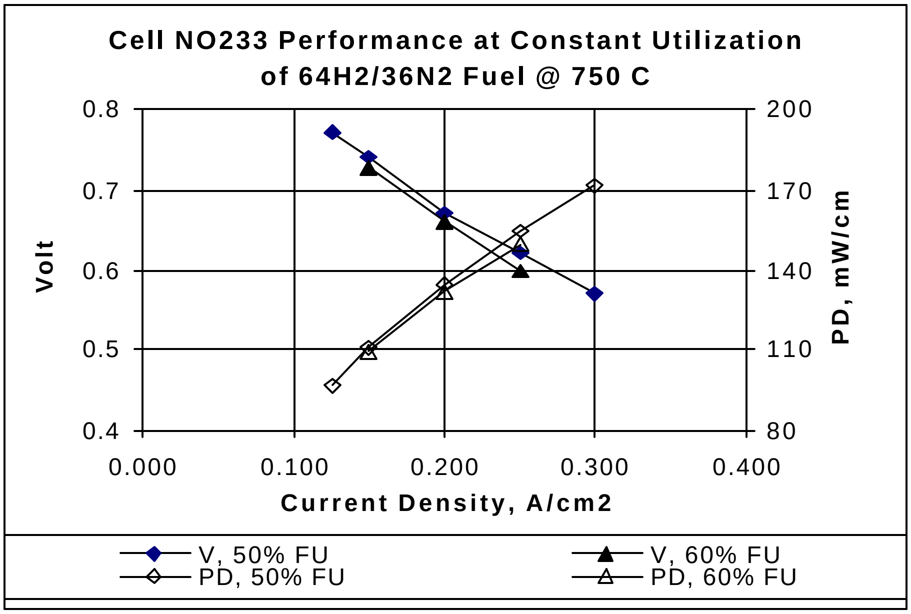

Figure 4. Cell NO-233 Performance under Constant Fuel Utilizations

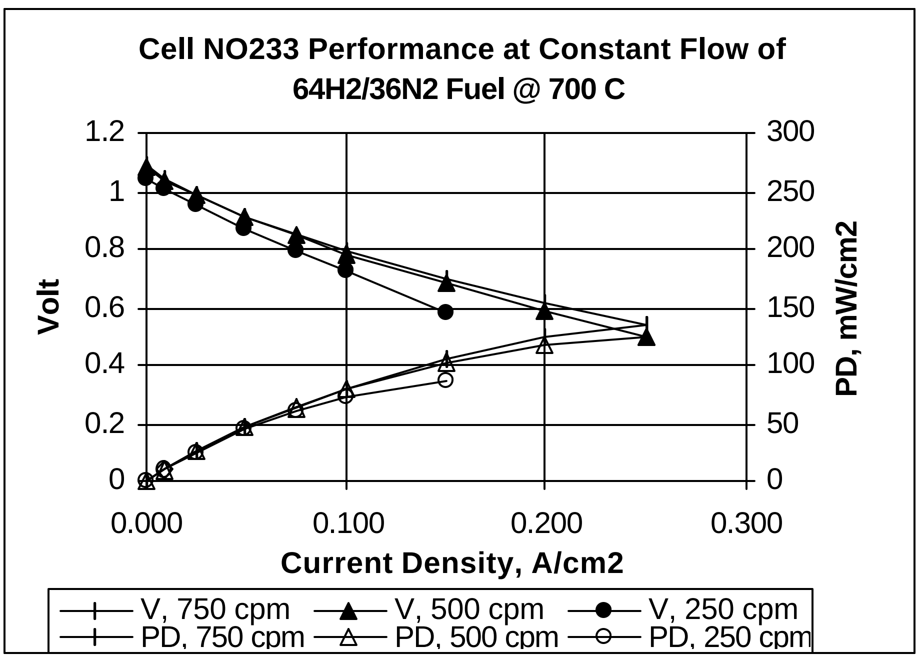

Figure 5. Cell NO-233 Performance at 700 C under Different Fuel Flow Rates

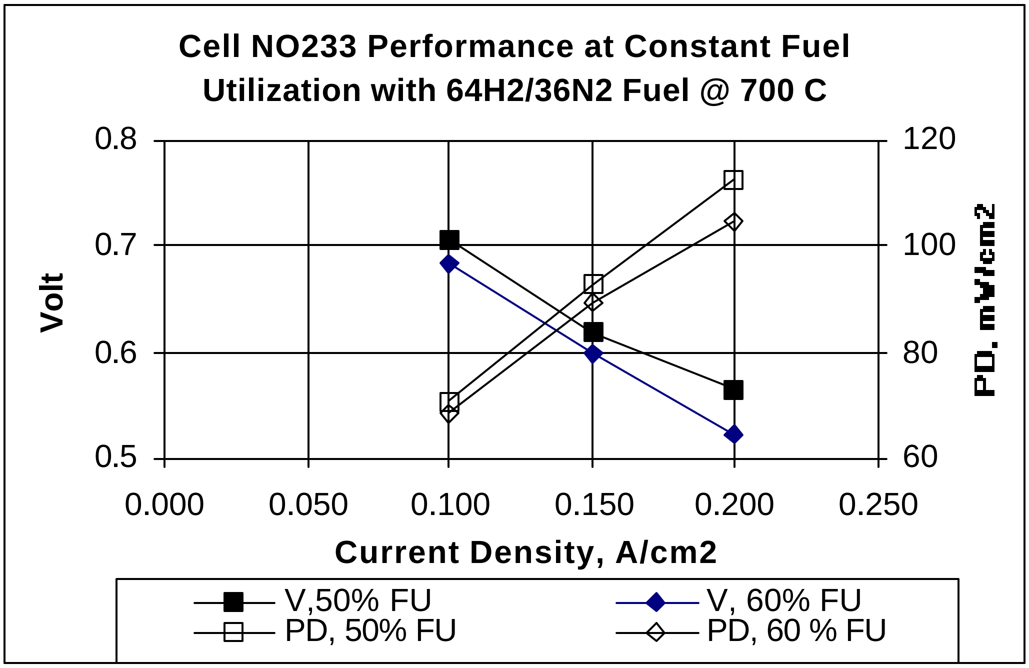

Figure 6. Cell NO-233 Performance at 700 C under Different Fuel Utilizations

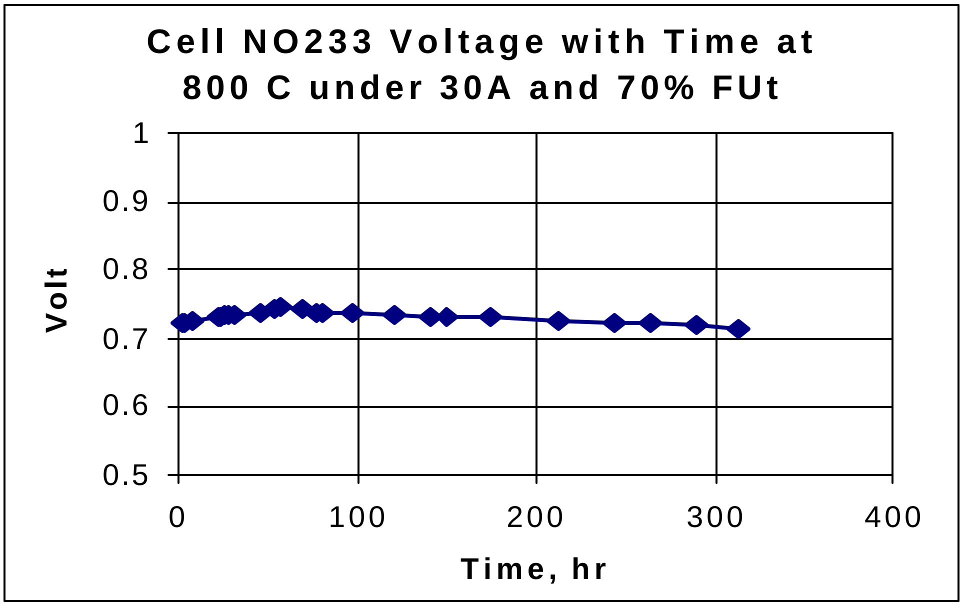

Figure 7. Cell Voltage with Time at 800 C

Subtask 4.2. Manufacturing Process Definition

Process flow charts for cell fabrication and unitized cell assembly will be developed for the manufacturing process. A scenario for a mass production plant will be described. Capital requirements and production related costs will be provided to Task 2.0. Manufacturing Cost Study.

This task will be activated in the later part of the year after the unitized cell processes have been standardized.

Task 5.0: Preliminary Testing

Subtask 5.1. Electrochemical Testing

Under this subtask, detailed electrochemical performance analysis of the unitized cell will be performed. Measurements will include performance sensitivity to gas flow rate, temperature, current density and flow pattern. Design improvements will be made as needed to obtain the maximum performance possible.

There was no significant activity under this task

Subtask 5.2. Destructive and Nondestructive Evaluation (NDE) Testing

The objective of this subtask is to define destructive and non-destructive analytical techniques for ensuring cell quality at the various stages of the manufacturing process. Examples of analytical tools to be evaluated include radiography, ultrasound and digital microscopy for the cell and CT examination for stacks.

There was no significant activity under this task.